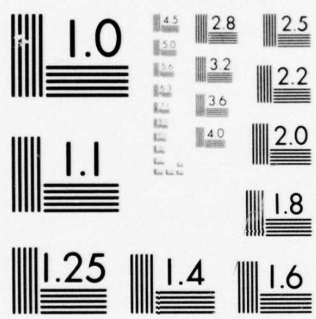
AD-A040 349 FRANKFORD ARSENAL PHILADELPHIA PA F/G 11/6
PROCESS STUDIES COVERING HOT SHEARING CONCEPT OF BILLET SEPARAT--ETC(U)
JAN 77 D O GUSTAD
UNCLASSIFIED FA-TR-77006-VOL-2 NL

1 OF 1
AD A040349

END
DATE
FILMED
7-77


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0

AD

FA-TR-77006

PROCESS STUDIES COVERING HOT SHEARING CONCEPT OF BILLET SEPARATION

VOLUME II of III

by

National Presto Industries, Inc.

January 1977

Approved for public release; distribution unlimited.

Manufacturing Technology Directorate

U.S. ARMY ARMAMENT COMMAND
FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA 19137

DISPOSITION INSTRUCTIONS

Destroy this report when it is no longer needed. Do not return it to the originator.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: FA-TR-77006 - Vol-2	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): PROCESS STUDIES COVERING HOT SHEARING CONCEPT OF BILLET SEPARATION. VOLUME II ~~OF III~~.		5. TYPE OF REPORT & PERIOD COVERED: Final Engineering Report.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): DUANE O. GUSTAD		8. CONTRACT OR GRANT NUMBER(s): DAAA25-74-C-0624
9. PERFORMING ORGANIZATION NAME AND ADDRESS: FRANKFORD ARSENAL, SARFA-MTT-F, PHILADELPHIA, PA 19137		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: MM&T PROJECT NO.: 5726358 & 5736358
11. CONTROLLING OFFICE NAME AND ADDRESS: FRANKFORD ARSENAL, MANUFACTURING TECHNOLOGY DIRECTORATE, PHILADELPHIA, PA. 19137		12. REPORT DATE: January 1977
		13. NUMBER OF PAGES: 52
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report): UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

V2 A040 365

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

142 720

18. SUPPLEMENTARY NOTES

This project was accomplished as part of the U.S. Army manufacturing technology program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in production of Army Materiel.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hot Shearing
Hot Flame Cutting
Hot Billet Separation
Billet Separation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The hot shearing and hot flame cutting concepts of billet separation for use in projectile forging applications were investigated during this project. The hot parting concept of billet separation involves heating 20 to 24 foot lengths of billet stock to forging temperature, hot shearing to required mult length afterwhich the hot sheared mult moves directly to the forging press. Using this concept of billet → over

20. ABSTRACT (Cont)

separation, heating to forging temperature, parting to mult length and forging can be accomplished as a completely integrated, synchronized and automatic operation.

Hot shearing studies were conducted on the 105 mm M1 and 155 mm M107 projectiles. Hot shearing was determined to be a completely satisfactory method of billet separation for projectile manufacture. Benefits which can be achieved from use of hot sheared mults are derived from reduced material handling, reduced material waste, reduced operating cost and improved projectile cavity surface finish.

Hot flame cutting was determined to not be a successful process for parting of mults for projectile manufacture. Slag and molten metal caused problems in subsequent forging operation.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont)

TABLE OF CONTENTS (Cont)

VII. LIST OF ILLUSTRATIONS (Cont)

I. INTRODUCTION

On 25 June 1974, a study was initiated to investigate the hot shearing of billets prior to the forging operation in the manufacture of artillery projectile bodies. The study involved heating billet lengths of steel to forging temperature, hot shearing the heated billet to mult length, and forging the parted mult. The forging was then to be processed thru the nosing operation with visual and magnetic particle inspections performed after the forging operation and after the nosing operation. Operations were performed using 3½" Round Cornered Square billets to produce 105MM, M1 artillery projectiles. The study comprised the following four phases:

PHASE I. Design and build new equipment and modify existing equipment as needed. Install government-furnished hot shear press.

PHASE II. Operate all equipment on trial basis and debug line. Perform hot-shearing operations to establish process parameters using 1018 steel.

PHASE III. Using parameters established in Phase II, fabricate 1,000 projectiles thru nosing using hot-sheared mults of 1018 steel.

PHASE IV. Hot-Shear 100 mults each of HF-1 steel and 1046 steel to compare results of shearing with those of 1018 steel.

II. PHASE I.

A. GENERAL

The equipment required for the study included a bar conveyor, a bar indexing mechanism, and an induction type bar heater, all of which were built at NPI in accord with the NPI Technical Scope of Work dated 27 February 1974 and submitted as part of Solicitation DAAA25-74-Q0236. The hydraulic shear unit itself was government furnished equipment.

B. BAR CONVEYOR

The bar conveyor consists of a stand fitted with pairs of rollers in the form of a vee. The conveyor is made in two sections, with a space between to permit a fork lift to lower 21 foot bars onto it. The complete unit is long enough to accommodate a full 21 foot length billet.

C. BAR INDEXING MECHANISM

The bar indexing mechanism is of the walker or "hitch-feed" type in which the bar is gripped between a pair of jaws and moved forward, after which the jaws retract and return to the initial position and repeat this cycle. All motion is provided by hydraulic cylinders. An arrangement of limit switches allows operation in the full automatic mode. A manual pushbutton override control is provided for all functions. Cycling is controlled by a timer which feeds at a rate compatible with induction heater capacity.

D. INDUCTION HEATER

The induction-type billet heater consists of two sections, the first operating at 60HZ, 350 KVA, supplied directly from the line, while the second section is rated at 960HZ, 100 KVA, powered by a motor-generator set. The coils and capacitor bank are watercooled with failsafe controls. Heat output is controlled by varying the motor-generator field.

E. HOT SHEAR PRESS

The government-furnished hydraulic hot shear press was manufactured in Germany by Rheinstahl-Wagner under the model number WSO-225-25. It has an effective shearing force rating of 225 metric tons and a clamping force of 25 metric tons at a maximum system pressure of 3550 psi. It is capable of hot shearing steel bars up to 7" square. It is equipped with a roller conveyor to carry the sheared mult six feet beyond the shear point. Manufacturer's specifications are shown on page 40.

The shear press and associated equipment were installed on a flat, undisturbed concrete floor as required by NPI. Since the manufacturer's specifications required pits beneath the floor to carry some of the high pressure piping and further required that the piping not be modified, it was necessary to raise most of the hydraulic components above the floor by means of steel supports. The installation is shown in the photos on pages 38-39.

III. PHASE II.

A. DEBUGGING OF HOT SHEAR LINE

No major difficulties were encountered in getting the hot shear line into operation. The bar indexer required a change in stroke length to achieve proper functioning and minor relocation and adjustment of some limit switches. No problems were encountered with the bar conveyor or bar heater. The shear unit itself only required adjustment of several limit switches and bleeding of air from hydraulic lines. All adjustments and changes were made over the first few weeks of operation while work to establish operating parameters was being carried out.

B. ESTABLISHMENT OF OPERATING PARAMETERS

It was possible to vary three operating parameters in the hot shear process: billet temperature, shear blade clearance, and shear blade speed. Each of these will be examined in turn. The stratagem was to begin with a given blade clearance setting and shear samples through the chosen temperature range, using the minimum stroke speed setting, then repeating for the maximum stroke speed setting. This process was performed for each of four shear blade clearance settings. A discussion of each parameter follows:

1. Billet Temperature. The billet temperature was checked at the anticipated shear zone immediately before each cut was made, using a Mikron Model 10-D Portable Infrared Thermometer with a $\pm$ 10°F. accuracy. The instrument was zeroed and the billet hand-descaled in the shear zone before

each reading was taken. Temperatures were held to 25° increments over the range. The normal forging temperature of 1950° used at NPI was taken as a starting point, after which higher and lower temperatures were tried until unacceptable sheared face quality was observed, or until the upper and lower limits of 2250° F. and 1500°F. respectively were reached.

2. Blade Clearance. Shear blade clearances were adjusted by means of shims behind the lower blade. It was decided to use the manufacturer's recommended minimum clearance of .5 millimeter (approx. .020) and maximum of .7 mm (approx. .028) as well as clearances below and above those values (.015" and .037" respectively).

3. Stroke Speed. The speed of the shear blade while cutting is adjustable over a limited range. Speed is also load-dependent except when the ram pressure exceeds 1400 psi (corresponding to 89 tons force) after which the speed is regulated to the setting regardless of load, up to the full tonnage. The minimum and maximum speed settings represent approximately 144"/minute and 200"/minute respectively.

C. RESULTS

All samples were photographed and arranged as shown on the chart on page 40 for comparison. Orientation of the samples on the chart is such that movement of the shear blade and of the sample would be to the upper right. The end of the sample shown is the drop end, or the end last sheared, which is invariably of equal or poorer surface

quality than the other end or clamped end. Thus, the "worst case" side of the shear cut is shown.

1. Effects of Shearing at Various Temperatures. As can be seen from the sample chart, cut quality will deteriorate as billet temperature decreases, beginning at progressively higher temperatures as blade clearance increases. The upper limit of temperature for shearing with acceptable quality is in excess of 2250°F., which was the highest temperature tried.

2. Effects of Shearing at Various Blade Clearances. The major effect of changing blade clearance is on the range of temperatures over which quality cuts may be obtained. As stated above, quality begins to deteriorate at progressively higher temperatures as blade clearance increases which means that the range of temperatures for quality cuts narrows correspondingly. The least blade clearance will yield the greatest temperature range for quality cuts.

3. Effects of Varying Stroke Speed. The results shown on the chart indicate generally that for a given blade clearance, cut quality will deteriorate at progressively higher temperatures as stroke speed is increased. However, results obtained showed some inconsistencies which agreed with observed inconsistencies of stroke speed while shearing. Exact control of speed could not

be maintained at all times, and some variation was noted while shearing. This was due to the fact that the shear was operating in the unregulated, load-dependent zone and also due to the vagaries of hydraulic systems generally, such as entrained air and variations in oil temperature and viscosity. Thus, the results may indicate a trend but are not completely reliable.

4. Conclusions. By examination of the test results, the final parameters were chosen for operations in Phase III. The temperature range for shearing was chosen to be 2000°F. ±50°, which is 50° higher than the normal forging temperature used at NPI. Observations of temperature loss from the time the billet enters the shear to the delivery of the mult at the end of the roller conveyor showed the loss to be 50° or less. This would correspond to the delivery of a mult to the forge press at forging temperature if the shear was set up in a shell production situation. Also, this temperature is well within the proper range for quality cuts.

The blade clearance chosen was .020", the manufacturer's recommended minimum value. While the lowest (.015") clearance gave a wider "safe" range of temperatures, it was felt that there was no practical advantage in using it, in fact, being outside the recommended range, it could lead to some as yet undisclosed difficulty.

The blade speed was set at "Maximum" which corresponds to approximately 200"/minute, and was chosen to most closely approximate production conditions.

Achievement of a "quality cut" or a cut that produces acceptable forgings, was assumed to be one on which the surface is flat, smooth, and free of any breaks, cracks, or lip. Slight striations would be permissible. Face angle would deviate no more than 2^{o} from 90^{o}. The parameters finally chosen produced cuts which fulfilled these conditions.

IV. PHASE III.

A. SHEARING OF 1018 STEEL - 1000 MULTS

The plan required by the contract involved shearing and forging projectiles in groups of twenty-five, followed by visual and magnetic particle inspection after forging and nosing of each group to assure that no shearing related defect conditions needed correction before proceeding with further work. Groups of twenty-five were to be forged until all problems were resolved, followed by groups of one hundred. The final group of five hundred was to be forged as one group. The magnetic particle inspections were carried out according to the MIL-I-6868 in effect at the time.

B. RESULTS

1. Defect Conditions in Forgings and Nosed Shells. The actual forging, nosing and inspections were carried out as follows: Two groups of about 25 each; one group of 50; one group of 100; two groups of 150; and the final group of of 500 pieces. The visual and magnetic particle inspections

performed on the forgings and nosed shells revealed no defects whatever that were related to the hot shearing process. Internal finish was considered equal to that obtained in normal production. The inspection revealed only one prevalent type of unrelated defect, that of external seams which were of a type and frequency normally found in regular production.

The standard 105MM hot-cup-cold-draw process was used throughout, with the exception that the mults were not shotblasted before forging. Orientation of the mult ends entering the forging die was completely random.

2. Control of Mult Weight. A sample of eighteen pieces was checked for weight. The average weight was 29.588 lbs. with a range from 29.48 to 29.70 or .22 lb. This is well within the contract requirement of $\pm$ 1/2 lb. and also within the NPI 105MM Spec of $\pm$.2 lb. The variations arise from variations of weight per foot in the steel as received, plus small variations in mult length due to variations in exact point of contact on the bar stop and variation of the exact point of entry of the upper shear blade. Thermal expansion and contraction over the shearing range also contributed to the weight and length variation. Tabular data on mult weight may be found on page 41.

3. Sheared Mult End Condition. The following information regarding mult end condition was tabulated for both the drop end of the mult (the end last sheared) and for the clamp end (the end first sheared; the end remaining clamped in the shear from the previous mult separation). The distinction is made because the clamp end tended to show different results than the drop end. In addition, data was gathered with a work support device in place under the mult being sheared. This was done because the roller conveyor which supports the billet end prior to shearing is moved several inches down below the billet when the shear ram descends, thus removing any support from under the mult during at least the first half of the shear blade movement thru the billet. The support device was made in the form of a V-block as shown in figure page 44, and placed under the billet end prior to shearing. The roller conveyor was displaced downward by manual control just far enough for insertion of the V-block which then rested lightly under the billet. Once downward movement started, full hydraulic support of approximately 2½ tons was provided.

Tabular information regarding mult end condition is provided on page 41, including raw data as well as mean and range figures.

Photographs of a typical hot sheared mult are on pages 42 and 43.

a. Burrs or Lips. A faintly discernable lip was found on a large percentage of mults, of a size that could barely be felt with the finger. The lips were located on the lower corner of the mult, extending in the direction of shear blade movement. No evidence of any effect from the lip could be found in the forgings.

b. Deformation. The mult ends were deformed in two ways: bending and out-of-square.

Bending was measured by taking the distance from the upper corner of the mult at the sheared face to a straight edge laid along the axis of the mult on the upper edge. (See Page 45.)

Another measurement was taken in a similar manner 3/4" back from the sheared face. The difference between these two measurements gave a figure from which a "bend angle" could be calculated. This method is arbitrary but serves as a convenient means of comparing the degree of deformation present.

The squareness of the mult end was obtained by taking the diagonal measurements with a dial caliper, the legs of which were held parallel to the axis of the mult along the corner radii. (See Page 45.) The difference of these two gives an out-of-square figure, which is presented in Table on Page 41.

c. Perpendicularity of Sheared Face to Axis of Mult.

Face angle was measured by setting the sheared end of the mult on a plane surface and measuring the deviation of the mult axis at a point 6" from the sheared face by means of a dial caliper and square. The angle by which the face deviates from 90° to the mult axis is calculated from this data and is expressed in degrees and minutes in the Table on page 41.

V. PHASE IV.

A. GENERAL REQUIREMENTS.

The contract required that 100 mults each of 1046 steel and HF-1 steel be sheared to compare the sheared ends with those produced in Phase III. Procedures to establish the operating parameters were to be repeated if needed. It was decided to test the temperature effect, using the stroke speed and blade clearance settings established in Phase III. In addition, blade clearance just above and below the manufacturer's recommended minimum setting were examined for 1046 steel.

B. RESULTS WITH 1046 STEEL

The photos on page 46 show the sheared samples. Again, it can be seen that the lower limit of billet temperature for shearing with acceptable quality will increase with increasing shear blade clearance. The mult ends sheared at the .020" clearance without support show a flaked or broken surface at one corner at the upper temperatures. The reason for this is unclear, although the effect is similar to that found on HF-1 mults. It does serve to establish the upper limit of shearing temperature for acceptable quality at 2150°F. for the .020" clearance. Use of the V-block support did

prevent the appearance of the flaking up to the maximum temperature tried, 2250°F.. However, quality of sheared ends was also acceptable to 2250°F. for .015" and .028" without the support in place.

The required lot of 100 mults was sheared at 2000°F. ± 50° and at .020" and maximum stroke speed. Visual inspection of these showed surface finish equal to that of the 1018 steel. A sample of 25 mults were weighed and measured for squareness, bending, and perpendicularity of sheared face. The mean and range values are given on page 47.

C. *RESULTS WITH HF-1 STEEL.*

The trial with HF-1 steel involved shearing at the manufacturer's recommended minimum blade clearance of .020". The lowest temperature consistent with good quality sheared ends was 1800°F. and the highest 2000°F. The same flake effect as found with 1046 steel was apparent at 2050°F. and 2100°F. At 2150°, some localized melting was apparent. For shearing of the required 100 mults, the .020" clearance at maximum stroke speed was used, at a temperature of 1950°, ± 50°F. Visual inspection of the mults indicated a sheared surface quality equal to or better than 1018 mults. A sample of 25 mults were weighed and measured for squareness, bending, and perpendicularity of sheared face. The mean and range values are given on page 47 and photos of samples are on page 46.

VI. DISCUSSION

The contract requires presentation of data on costs and production efficiency obtained from elements of the process parameter information. This information is to be extrapolated to provide cost projections as though the process were used on a regular production basis. It is to be understood that since the hot shear has not been applied on a production basis, projections regarding costs of initial and sustained tooling, all labor and maintenance costs, and especially actual production rates and shear press efficiency are estimates only. The many inputs used in arriving at each such estimate are subject to wide variations.

The Rheinstahl/Wagner shear unit used in the performance of this contract is not of a size that would support forge press equipment operating at a rate such as that at NPI; thus attempts to use cost projections for comparison with the NPI experience would not be meaningful. Extrapolations of cost data such as tool life and maintenance expectations, while useful at the production rate of the R/W unit, cannot readily be extended to apply to rates encountered at NPI due to the non-linear relationship between production rate and such variable costs.

The discussion that follows considers the R/W hot shear press alone as applied to a hypothetical production situation.

A. FACTORS RELATED TO INTEGRATION OF A HOT SHEAR IN A FORGE LINE.

1. Production Rate and Efficiency. The actual rate achieved by the system at NPI was one piece per 69 seconds or 52 pieces/hour. This rate was determined by the heating capacity of the induction heater rather than the shear press itself. Times of individual shear press functions were measured and are shown on the chart on page 48. The shortest possible cycle time with the shear set at maximum stroke speed and at zero load is 10.3 seconds which corresponds to 5.82 pieces/minute or 349 pieces/hour. The manufacturer has quoted a rate of 4.8 pieces/minute or 288 pieces/hour which is supposedly based on full capacity of 7" round cornered square stock.

   Since operations were not conducted under production conditions during the course of study, no efficiency factor can be stated.

2. Costs.

   a. Capital Costs Including Tooling. The price charged by Rheinstahl-Wagner for the Hot Shear press, complete with tooling and hydraulic fluid, was Dm 569,245.50 which at current rates ($.39) is $222,000.

      This does not include capital cost of the billet heater, power supply or bar indexer/conveyor equipment, nor does it include installation costs for any part of the shear line.

According to Girard Associates, the U. S. representative for Rheinstahl-Wagner, replacement tooling is generally supplied by the user's own toolroom facilities. Girard was reluctant to indicate a factory replacement price for tooling, stating only that it would be "unrealistically high". They made a rule of thumb estimate of cost for user-built tooling of $300 per set of knives, with regrind cost at 1/3 to 1/2 of tooling cost. A quote obtained by NPI from a tooling vendor for one complete set of shear knives was $2871 per set and $2076 per set for two sets with a regrind cost of $725. See table on page 49 for tooling cost per cut information.

b. Operating Labor Cost. The shear press will normally be operating as a part of a forge line and may not require a separate operator. However, at least a fraction of a man-hour per operating hour would be required of the forge line crew to handle startup and maintain normal vigilance over the hot shear press. While a time study would need to be performed on the forge line operating crew to establish the exact time, approximately one-half man-hour per operating hour is felt to be a reasonable estimate. Manpower requirements for the billet heater and conveyor/indexing mechanism will vary with the type of equipment employed and are not included.

c. Maintenance Labor Costs. The routine maintenance labor which involves lubrication, checking accumulator charge, filter changing and tool changing is estimated to require 3.2% of operating time and 1.6 maintenance personnel, or .05 man-hours per hour of operating time. Non-routine labor costs which include maintenance shop hours, overtime and time used in breakdown repair consume an additional .066 man-hours per hour of operating time. The total maintenance labor hours then would be 14.16 per 120 hour workweek.

Due to the high volume usage anticipated, the possibility of a major overhaul as often as every two years should be considered.

d. Operating Costs.

1) Electrical. The shear press requires 128 kilowatts of three phase power. The bar indexer requires a maximum of 7.5 kilowatts. The major electrical cost is for heating of steel; in the case of 3½" RCS bars, heating to 2000°F. requires about .126 kWh per pound of steel or about 3.7 kWh per mult.

2) Cooling Water. The Hot Shear Unit requires water for cooling in three areas:

(a) Oil Cooler. The water requirement is approximately 30 gpm when hydraulic fluid temperature exceeds 122°F.

(b) Tool Cooling Circuit. The water requirement is approximately 30 gpm.

(c) Roller Conveyor. Water requirement is approximately 15 gpm. Cooling is obtained by direct spray on the rollers and also serves to wash scale from them. Spent cooling water would require removal of contaminants before returning to the plant system. In the case of NPI installation, this circuit was not used due to the limited level of production.

3) Lubricants. Usage of lubricants is nominal. Two types are used: a lithium grease for the central lubricating system and a high temperature molybdenum disulphide grease for manual lubrication of the roller conveyor bearings.

4) Hydraulic Fluid. A fire resistant phosphate ester fluid is used in the hydraulic system. Usage of fluid is limited to replacement of leakage losses. Life of the fluid is maintained by testing for contaminants periodically and applying a suitable reconditioning regimen when indicated.

5) Air. Compressed air is required for precharging the hydraulic fluid reservoir and for raising of the roller conveyor. In both cases, the major air requirement exists only at startup, with minimal air required during operation to handle leakage losses. The air supply should be at 90 psi minimum.

e. Support Facilities.

1) Material Handling Requirements. In the NPI installation, a forklift was used to transport individual billets to the conveyor. In a production situation, a handling table or unscrambler system would be employed. Crane equipment would be needed to handle the bundles up to that point.

Some means must be provided to contain the short billet ends and rejected mults that are delivered from the side of the shear unit.

A conveyor section or transfer device would be needed to move the hot mult from the end of the roller conveyor into the forge die. It is possible that such a device could completely supplant the roller conveyor provided with the shear unit.

2) Descaling Equipment. Consideration of forge die life indicates that some means of descaling the hot mult should be included between the shear press and the forge press. An alternate method would be to descale the billet before heating. Experience at NPI with sawed, shotblasted mults has shown that some scale accumulation during heating can be tolerated.

3) Weight Control Devices. In the setup at NPI, mult weight was controlled by weighing the first mult from each billet and adjusting the end stop accordingly. Mult weight was then checked at least one more time per billet. In full production, an automatic mult

weighing systems could be employed, either with a readout available to the operator to allow manual resetting of the endstop, or tied electrically to the endstop control in a closed loop feedback arrangement. An alternate method would employ a feed-forward control where the full billet is weighed automatically before entering the induction heater.

4) Introduction of Salvage and Reheat Mults into the Forge Line. Since some mults may be turned off the line during press stoppages, they must be reheated and introduced into the line. Also, any external form of billet end salvage system will produce cold mults which must be brought to forging temperature. Heating equipment must be provided to handle these requirements. An entry point in the line after the hot shear must be provided for individual hot mults. This would also be a requirement where a system for salvaging a hot mult from a billet end is employed.

f. Material Losses.

1) Losses Due to Billet Length Inaccuracy. The length of the billet before shearing must be a minimum of one mult length plus the width of the billet. That is, to allow adequate clamping, the least

amount of stock left after shearing the last mult from a billet must be equal to the billet section; for 3½ RCS billets, this would be 3½". If less than this amount remains, the billet would be diverted out the reject chute without shearing. Such billets would measure mult length + 3½" or less in length and would be salvaged by cutting to mult length with a saw or some other means.

Mill length billets should measure a multiple of mult length plus 3½" with a tolerance of minus zero, plus normal mill tolerance. Billets falling outside this length range will yield either more than minimum scrap or one mult per billet that would require salvage trimming. Thus, the maximum scrap due to billet length variation and clamping loss would be 3½" more than the maximum mill tolerance for billets within tolerance. Minimum scrap without salvage cutting a mult would be 3½". Economic analysis may demonstrate that it could be feasible to eliminate the clamping allowance and provide a billet end salvage cutting system. If one mult per billet is salvage cut by some means, scrap will not exceed the maximum mill tolerance.

The billet ends which are to be salvage cut to length to produce usable mults can be dealt with by several means.

Billet ends could conceivably be sheared to correct length if a work support clamping system were provided which moved downward with the upper blade and which provided a clamping force equal to that of the billet clamping tonnage.

An alternative method would be to stop the back end of the billet exactly one mult length before the shear blade opening by some means. In either case, the short piece of trim scrap could sometimes fall from the lower "V" of the blade before the reject chute could swing into place. A means of carrying away the trim scrap would have to be included in any such design change. It is possible to shear as little as 1/8" from the mult end and still achieve a normal sheared face condition on the mult. The illustration on page 50 shows a mult from which 3/8" was sheared. The shear blade was stopped just short of severance to show the amount of scrap removed. It can be seen that the sheared surface is normal in every respect.

A third method is to provide a means of salvage cutting external to the shear unit. This could be any hot parting method such as hot sawing, milling, or flame cutting. Cooling the mult and using some cold parting method can also be considered.

Due to the need for retracting the billet back into the heater for reheating, the billet end detection system and the reject chute were not used at NPI.

2) Kerf Loss. Due to the nature of the shearing principle, no kerf loss occurs in hot shearing.

3) Losses Due to Non-Straight Billets. The shear manufacturer has stated a requirement for straightness of no more than 0.4" bend in a twenty foot billet. The main reason for such a requirement is is to ensure accurate weight control with relatively long mults, as excessive bend results in variations in contact of the end stop limit switch. With short mults such as for the 105MM projectile, more bend can be tolerated. Bends exceeding twice this requirement were encountered in producing the contract quantity of pieces and caused no difficulty. The limiting factor in this case is the ability of the billet heater and conveying equipment to accept non-straight billets. By trial and error, a bend requirement of one inch maximum per 20'9" bar was arrived at for the NPI setup; however, this is not necessarily correct for other installations. Visual inspection and selection of billets was necessary to fulfill this requirement. Though no losses were incurred due to the requirement, in a production situation billets with excessive bend would either be rejected or salvaged by cutting in half.

g. Downtime for Tool Changes and Preventive Maintenance.

Downtime based on a 120 hour week would total 3.8 hours. This consists of 2.3 hours for tool changes and 1.5 hours for preventive maintenance. These figures are based on minimum tool life and non-concurrent maintenance activities.

3. Tool Life.

A statement made in a paper presented by the shear manufacturer's representative at Picatinny Arsenal in 1970 gave typical blade life at 30 to 50 thousand cuts. A recent statement made by the same organization based on experience at several U. S. installations gave a figure of 15 to 30 thousand cuts before regrinding. Typically, a tool may be refaced and reground six times or more. The limited experience gained during the operation of the hot shear under this contract did not allow assessment of blade life or blade wear.

4. Floor Space Requirements.

The hot shear press with its hydraulic pumps, tank and piping, requires a rectangular space about 9½ feet by 25 feet or about 240 square feet. The electrical control station and electrical cabinet may be independently located and require an additional 17 square feet. The shear is located at the end of the rectangular layout and the direction of the bar movement is at a right angle to the axis of the rectangle. This space requirement does not include the billet heater or conveying mechanism, and a production setup would require a larger

heater and different material handling facilities. At the NPI setup, the space occupied by the heater and the indexing/conveying equipment was 3 by 37 feet, about 111 square feet, plus 4 x 10 feet for the high frequency motor-generator set.

5. Safety Status.

   a. Handling of Hot Steel. While the mults themselves are handled automatically throughout, short ends and reject mults are ejected down a chute on the side of the shear into a tub. As a result, hazards typical to handling of hot steel are present.

   b. Electrical. No unusual hazards exist with the hot shear press or the billet heater when provisions of the National Electrical Code and good commercial practice have been followed.

   c. Handling of Hydraulic Fluid. A phosphate ester fluid is used for the hydraulic medium in the hot shear press due to its fire-resistant qualities. The major hazard is the harmful effect from ingestion of the fluid, so cleanliness in the work area and good worker hygiene is important. Danger from skin absorption is minimal, and inhalation of the vapor phase is unlikely due to low volatility of the fluid.

   d. Noise. Measurements taken three feet from the circulation pump showed a noise level of 102 dB, which is the highest reading found in the system. However, operating personnel are normally located some distance from this point so no problems regarding OSHA compliance are expected.

e. Specific OSHA References. The only specific reference to billet shears in the OSHA standards is 1910.218(j)(1) which states that a positive lockout device must be provided to disconnect the power to the press. Other provisions must, of course, be observed where they apply.

6. Techniques to Yield Consistent Quality and Economy

   a. Bar temperature must be maintained within the limits. A plus or minus 50°F. tolerance is adequate for the steels used in this study.

   b. Repeated reheating of a billet or holding a billet at forging temperature for excessive periods must be avoided as this practice will lead to billet warpage and excessive scale formation.

   c. The shear blade and end stop must be kept in good condition, free of chips, burrs, or any deformation that will cause excessive grooves or striations on the sheared face. The shape of the "V" groove in the shear blade must be kept square with a radius conforming to that of the billet being sheared.

   d. If the end stop is to be manually controlled, the weight of the mult should be checked at least twice per billet.

   e. The length and length tolerance of billets from the steel mill should be specified by use of an optimization model which includes inputs on cost of short ends, cost of salvage cutting reject mults, and added cost of a closer-than-standard length tolerance specification.

B. ADVANTAGES/LIMITATIONS RELATED TO OTHER PROCESSES

1. Hot Parting vs. Cold Parting. The major disadvantage of hot parting (whether by shear, saw or other method) over cold parting techniques is that equipment must be integrated into a forge line, unless production reheating of forging mults is acceptable. When the parting equipment is integrated, its production rate is subject to any stoppage in the system and also is limited by maximum heating capacity and forge press rate. Cold parting equipment can be operated separate from the forge line allowing greater efficiency thru stockpiling and independence from forge line stoppages. However, cold parting techniques require more energy and have a generally higher cost per cut for tooling. **Hot parting systems require that the forge line have a means of reheating individual mults and introducing them into the line.**

2. Cold Shearing. An advantage of cold shearing is that cycle rates are generally higher and the rate is not dependent on billet heating capacity. Because of this, one cold shear may be able to feed more than one forge press. However, the tonnage required is higher than for hot shearing and tooling stresses are also higher. End condition of the hot sheared mult is superior to that produced by cold shearing. Cold shearing has been successfully practiced in the forging industry for some time.

3. Flame Cutting. Flame cutting can be used for separation of mults from both cold billet stock and that heated to forging temperature. Capital cost of equipment is very low, but is quickly offset by high costs for gasses and the large kerf loss. The high cost per cut eliminates both these processes from serious consideration in high-volume forging operations. Mult end condition is acceptable for forging, but presence of slag and molten steel residue, especially in hot-cut mults, may necessitate special cleaning or end preparation techniques.

4. Sawing. NPI has had exhaustive experience in sawing mults of 1018 steel, having processed in excess of 90 million from 3½" RCS billet stock. The mult end condition which results from sawing is excellent, being about as smooth as a hot sheared surface. Overall end condition, including surface finish, out-of-square, bending and face angle, can be considered as unsurpassed by any other parting method suitable for high volume production. Capital cost for each saw is low, but the slow production rate means that five to twenty saws would be required to replace shear equipment. Cost per cut for tooling is comparable to shearing, but is equalled by kerf loss which is absent in shearing. However, the savings from lack of kerf loss in shearing is partially offset by the need for some means of salvaging the billet ends. Operating manpower requirements for sawing are high. Since sawing is a chip producing method, a means of

handling the chips is required, as well as provision for cutting fluid storage and recirculation. The cost of the cutting fluid itself is also a consideration.

C. CONCLUSIONS AND RECOMMENDATIONS

1. Hot shearing will produce a mult end condition suitable for production of 105MM shell by the Hot-Cup, Cold-Draw Process.
2. The temperature range for forging quality sheared ends is widest for low carbon steel, narrowing as steels with higher shear strengths are sheared.
3. Optimum shear blade clearance is the shear manufacturer's recommended minimum of .020".
4. Shear blade stroke speed does not have a significant effect on sheared mult end condition within the range of shear speeds available and steels used in this study.
5. HF-1 steel and 1046 steel may be hot sheared using the same parameters as 1018 steel except that the usable temperature range is narrower.
6. Extrapolation of data obtained on the Rheinstahl/Wagner shear unit to develop costs of hot shearing 3½" RCS mults does not yield realistic information since the shear is rated for approximately four times the tonnage required for shearing that size stock and has a correspondingly lower operating rate. Most cost factors would be lower for a shear unit properly sized for the task.

7. The R/W shear, like billet shearing equipment generally, is suited to shearing a range of billet sizes and mult lengths. As a result, the equipment is needlessly complicated for the single-purpose usage encountered in an integrated forge system.

8. The nature of this study did not permit the gathering of precise functional, cost, and efficiency data relative to integration of hot shearing into a production forging line. Such information can best be gained by full on-line operation of a correctly-sized hot shear unit fully integrated into a projectile forge line operating at the anticipated full production rate.

MANUFACTURER'S SPECIFICATIONS

Page 1 of our quotation to U.S. Army Frankford Arsenal, Philadelphia

1. 1 electro-oil-hydraulic hot shear
type VSö 225/25

effective shearing force, max.	225 Mp	225 metr. tons
down-holding force, max.	25 Mp	25 metr. tons
operating pressure, max.	250 kp/cm2	3550 psi
shear stroke, max.	365 mm	14.4"
cross section of billet to be cut, up to square bars of	178 mm	7"
with a hot tensile strength of 7 kp/mm2 = 10 000 psi		
billet lengths	230 - 600 mm	9-24"
total drive power required	105 kW	140 HP
calculated speeds, infinitely variable, with superposed power regulation		
advance, max.	200 mm/sec	480 ipm
cutting up to 100 kp/cm2 = 1400 psi, max.	90 mm/sec	210 ipm
at 250 kp/cm2 = 3550 psi, max.	35 mm/sec	83 ipm

2. 1 roller conveyor with a device
for dropping the bar ends

number of rollers	6 + 8 pcs.
speed of roller conveyor	600 mm/sec. 1400 ipm

lateral shifting of one of the conveyor sections	270 mm	10.5"
displacing speed	300 mm/sec	700 ipm
stroke of the lowering part	250 mm	10"
drive power	2 x 0.75 kW	2 x 1 HP

<u>Included in this delivery:</u>

the hot shear proper

the main and auxiliary pumps and base plates and couplings

the hydraulic control including prefilling valve

the tank for the hydraulic liquid

the filtering device for the hydraulic fluid

the heating and cooling device for the hydraulic fluid

the entire piping inside the machine and the hydraulic control system, and the connecting pipes between machine and hydraulic control system. The connecting pipes, however, delivered in straight commercial sizes only, together with flanges, sealings and bolts, to be fitted and installed on site

the central grease lubrication

the anchor bolts and washers for the machine

the shear blade holders

1 set of shearing blades

the roller conveyor with a device for dropping the bar ends arranged behind the machine

1 set of screw spanners

the cooling device for the upper and lower blade holders

the electrical equipment indicated under point 3)

Not included in this delivery:

the manipulating device for tool changing

the hydraulic fluid

the supply line for the cooling water

an automatic control for dropping the cropped end

the foundation covering

the device for removal of the dropped billets

3. 1 electrical equipment

laid out for an operating voltage of 460 V, 60 cycles three-phase AC current

Included in this delivery:

2 three-phase AC motors for the drive of the high pressure pumps

for each:

short circuit rotor

protection type IP 44 (totally enclosed, fan cooled)

construction type B 3 (foot mounted)

power, at 40 % duty time	50 kW	67 HP
speed	1200 rpm	

the three-phase AC motors for the auxiliary drives

the control inside the switch cabinet

1 control desk

the installation of the electrical devices at the machine proper up to the connecting terminal board

Rheinstahl
Maschinenbau
Wagner Dortmund

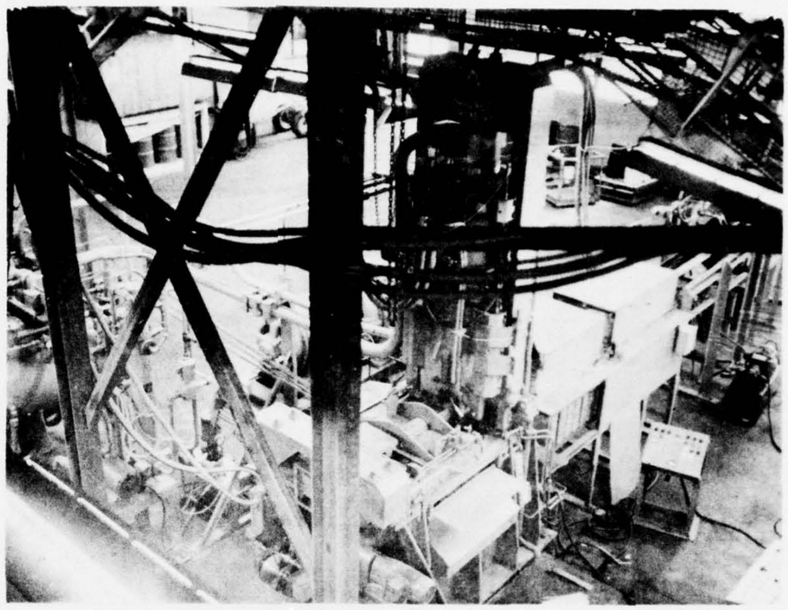
MANUFACTURER'S SPECIFICATIONS (Cont)

Page 4 of our quotation to U.S. Army Frankford Arsenal, Philadelphia

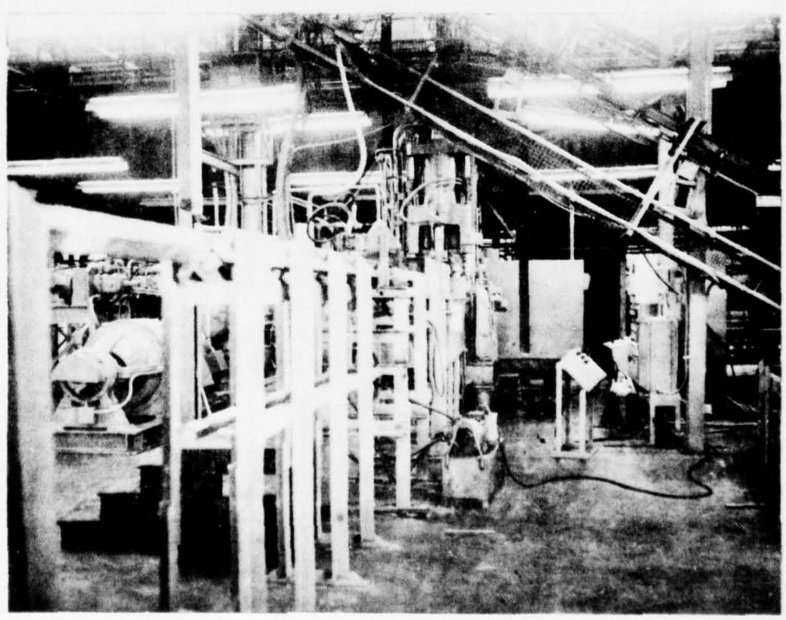
Not included in this delivery:

the connections between control cabinet, control desk and machine, as well as the installation of these cables in the foundation

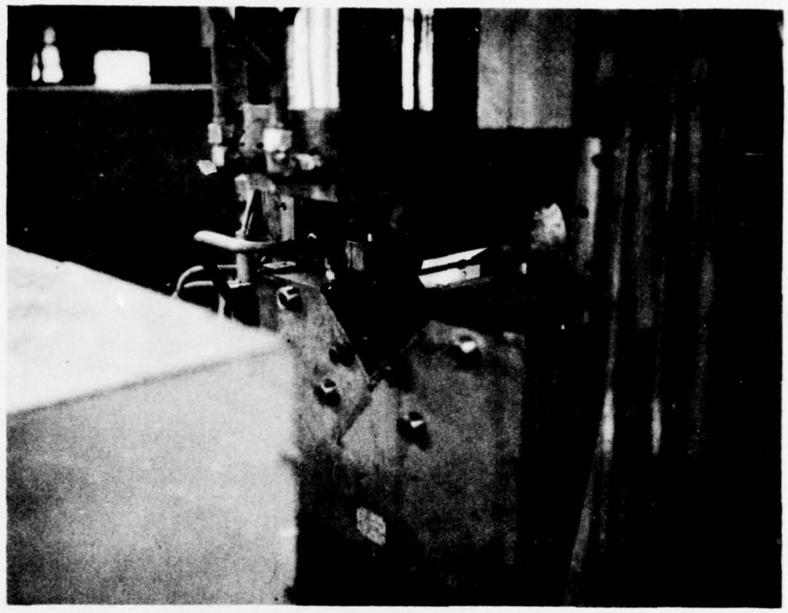
---



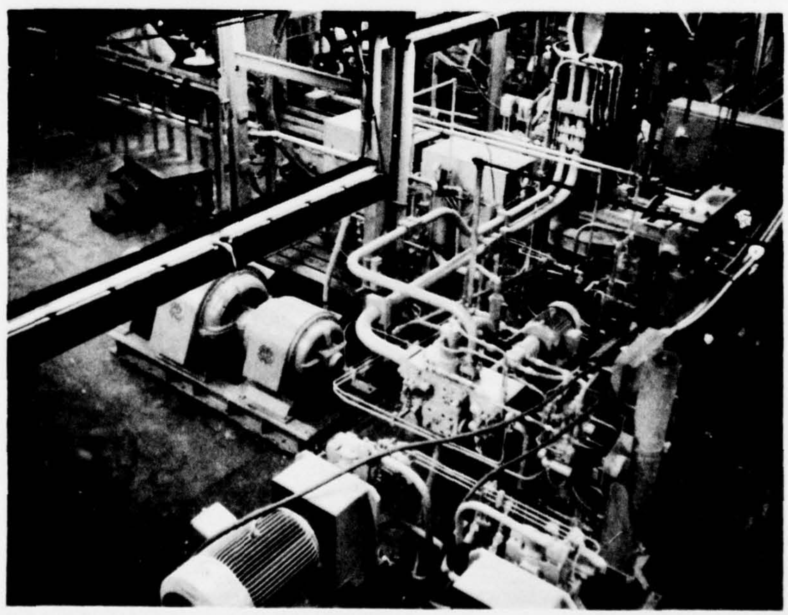
HOT SHEAR PRESS SHOWING OUTFEED SIDE. HYDRAULIC EQUIPMENT AT LEFT.



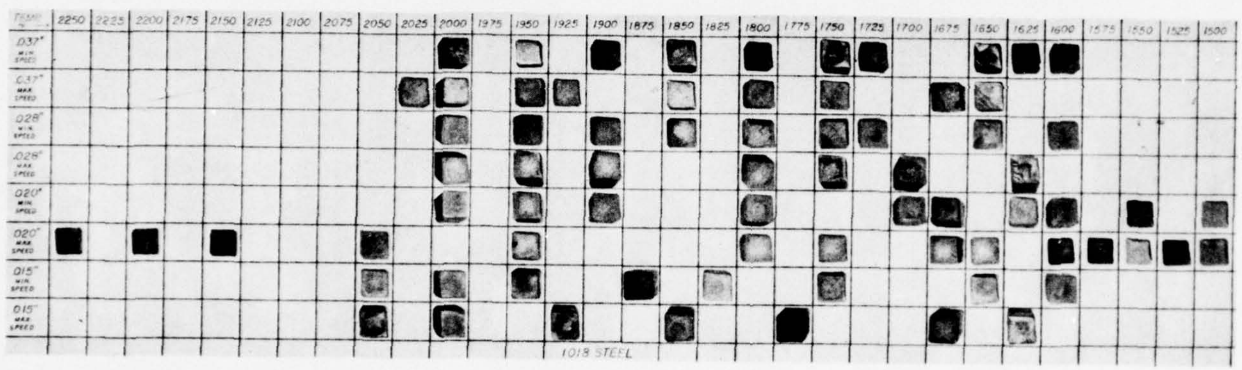
PRESS LINE SHOWING ELECTRICAL CONTROLS AT LEFT. PRESS IS AT CENTER, BAR CONVEYOR AT RIGHT.



POINT OF BILLET ENTRY INTO SHEAR PRESS. BILLET HEATER AT LEFT.



AERIAL VIEW SHOWING PUMPS, RESERVOIR AND PIPING, MOTOR GENERATOR SET.



PHOTOGRAPHS OF 1018 STEEL SAMPLES

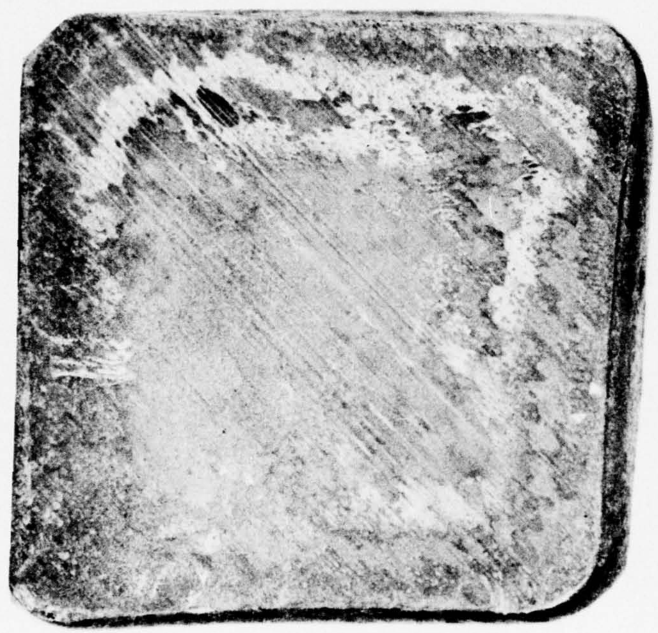
SAMPLE NO.	WEIGHT LBS.	CLAMP END: A* FACE ANGLE, MINUTES	CLAMP END: BEND B INS.	CLAMP END: BEND C INS.	CLAMP END: BEND D ANGLE DEGREES	CLAMP END: E-F OUT OF SQUARE, INS.	DROP END: G FACE ANGLE, MINUTES	DROP END: BEND H INS.	DROP END: BEND J INS.	DROP END: BEND K ANGLE, DEGREES	DROP END: L-M OUT O SQUAR INS.
NO WORK SUPPORT - MINIMUM STROKE SPEED											
84	29.10	38'	.295	.110	13°54'	.043"	0	.292	.105	14°0'	.077"
85	29.15	57'	.331	.127	15°12'	.061"	0	.354	.119	16°0'	.102"
86	29.54	58'	.316	.130	10°30'	.049"	0	.398	.134	19°24'	.095"
87	29.60	26'	.228	.080	11°12'	.066"	0	.310	.100	15°36'	.079"
88	29.40	29'	.288	.110	13°24'	.065"	0	.320	.092	16°54'	.088"
89	29.38	33'	.305	.124	13°36'	.045"	0	.413	.172	17°48'	.092"
90	29.39	46'	.331	.130	15°0'	.065"	0	.316	.108	15°30'	.094"
NO WORK SUPPORT - MAXIMUM STROKE SPEED											
91	29.51	47'	.290	.107	13°42'	.046"	57'	.400	.105	21°30'	.095"
92	29.67	41'	.328	.108	16°18'	.078"	0	.336	.083	18°36'	.049"
93	29.64	37'	.386	.093	21°18'	.043"	0	.332	.084	18°18'	.053"
94	29.69	29'	.250	.093	11°48'	.045"	0	.310	.106	15°12'	.058"
95	29.58	54'	.225	.079	11°0'	.057"	36'	.288	.094	14°30'	.050"
96	29.65	32'	.256	.087	12°42'	.063"	0	.278	.098	13°30'	.058"
WORK SUPPORT IN PLACE - MINIMUM STROKE SPEED											
97	29.59	29'	.264	.093	12°48'	.073"	0	.347	.108	17°42'	.045"
98	29.50	30'	.230	.074	11°42'	.058"	0	.332	.117	16°0'	.057"
99	29.56	25'	.227	.080	11°0'	.060"	0	.324	.104	16°18'	.074"
100	29.48	36'	.294	.105	10°42'	.066"	25'	.334	.100	17°18'	.060"
101	29.59	24'	.277	.104	13°0"	.064"	21'	.378	.142	17°30'	.061"
102	29.70	35'	.241	.080	12°6'	.060"	0	.338	.116	16°30'	.056"
103	29.60	20'	.288	.098	14°12'	.084"	0	.350	.100	18°24'	.069"
WORK SUPPORT IN PLACE - MAXIMUM STROKE SPEED											
104	29.60	32'	.276	.098	13°24"	.097"	21'	.334	.090	18°0'	.058"
105	29.51	32'	.324	.100	16°36'	.067"	18'	.301	.124	13°18'	.106"
106	29.53	18'	.296	.127	12°42'	.092"	0	.380	.122	19°0'	.064"
107	29.61	18'	.275	.113	12°12'	.098"	0	.357	.115	17°54'	.064"
108	29.58	26'	.302	.115	14°0'	.063"	0	.360	.110	18°24'	.064"
84-90 Mean**	29.366	41'			13°18'	.0562"	0'			16°30'	.0896"
Range	.50	32			4°42'	.023"	0'			5°24'	.025"
91-96 Mean	29.623	40'			14°30'	.0553"	15'			16°54'	.0605"
Range	.16	25			10°18'	.035"	57'			8°0'	.046"
97-103 Mean	29.574	28'			12°12'	.0663"	7'			17°6'	.0603"
Range	.22	12			3°30'	.026"	25'			2°24'	.029"
104-108 Mean	29.566	25'			13°48'	.0834"	8'			17°18'	.0712"
Range	.09	14			4°24'	.035"	21'			5°42'	.048"
Total Mean	29.588	34'			13°27'	.0643"	7'			16°57'	.0707"
Total Range	.22	40			10°48'	.055"	57'			8°12'	.061"

*See drawing of mult on page 46 for explanation of letter dimensions.

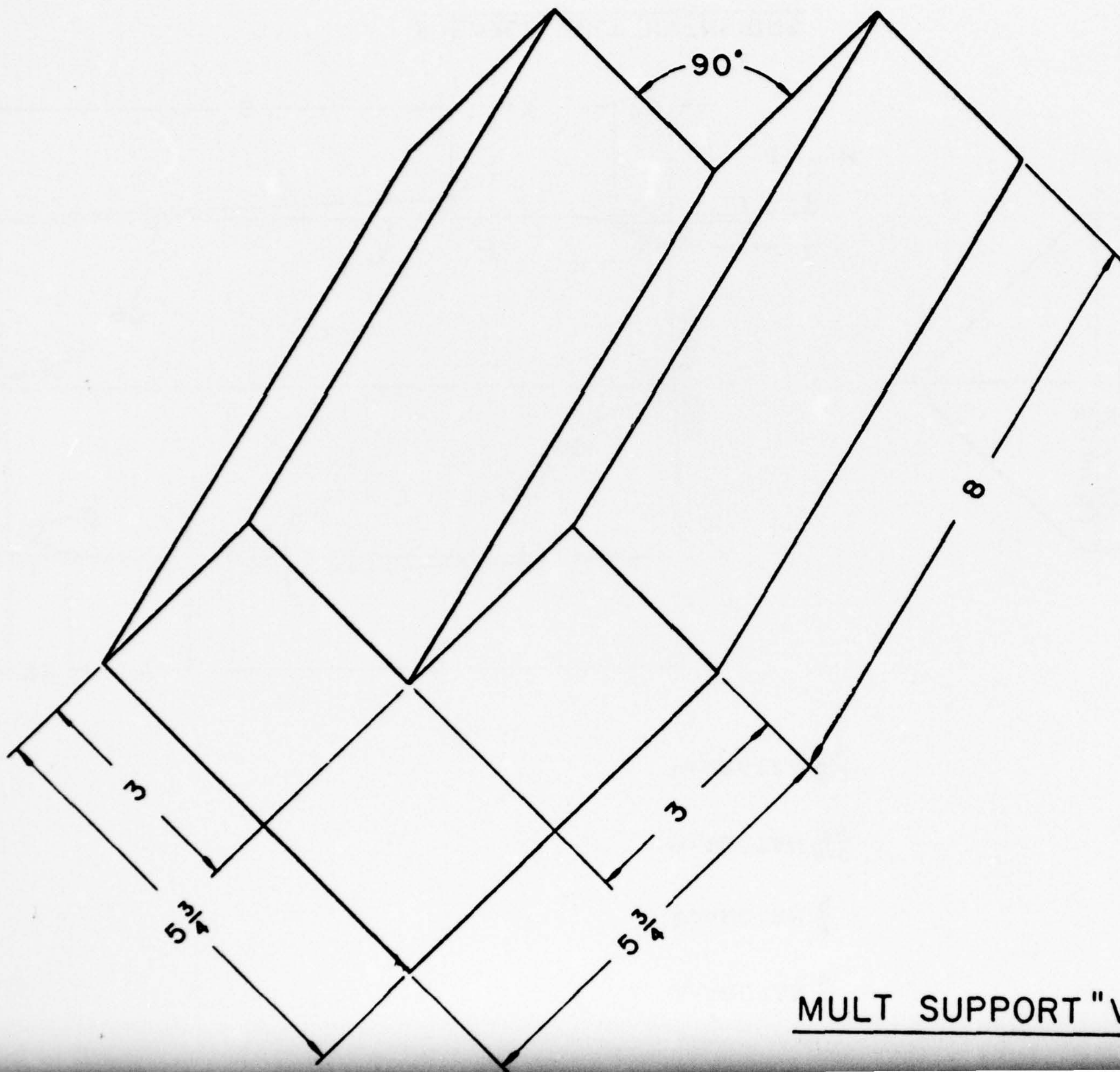
**Weight average and range not representative for Samples 84-90 due to several stop adjustments made while shearing. They are not included in total average and range.

DATA FOR 1018 STEEL

Side View of Hot Sheared Mult for 105mm M1 Projectile



End View of Hot Sheared Mult for 105mm M1 Projectile



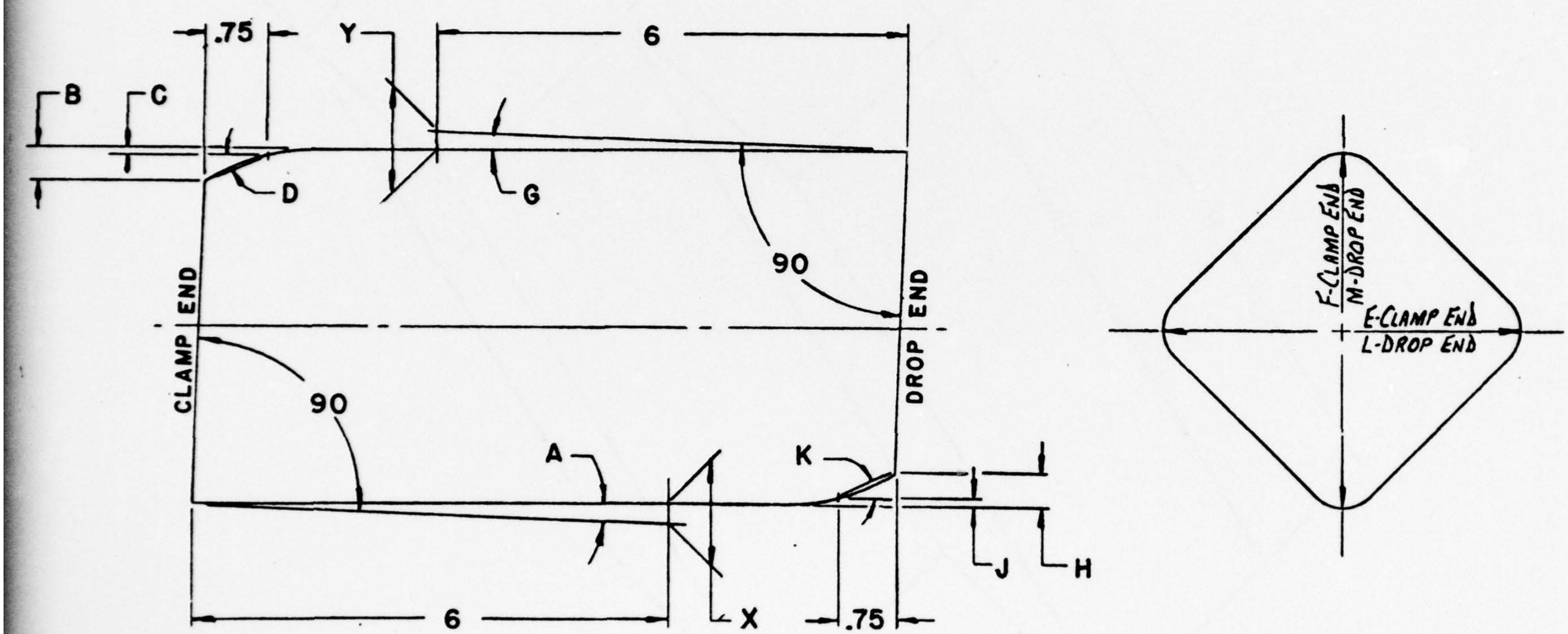
MULT SUPPORT "V" BLOCK

$A = \arctan \frac{X}{6}$

$G = \arctan \frac{Y}{6}$

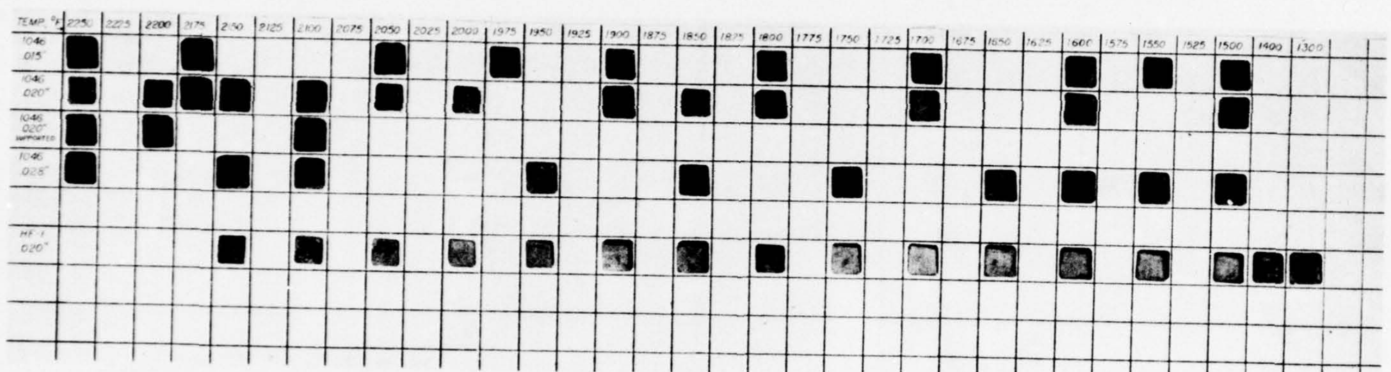
$D = \arctan \frac{B-C}{.75}$

$K = \arctan \frac{H-J}{.75}$



SHEARED MULT DIMENSIONS

(KEYED TO TABLE ON PAGE 40)



PHOTOGRAPHS OF 1046 AND HF-1 STEEL

DATA FOR HF-1 AND 1046 STEEL

		CLAMP END			DROP END		
	Weight Pounds	Face, Angle, Minutes	Bend Angle Degrees	Out of Square Ins.	Face Angle, Minutes	Bend Angle Degrees	Out of Square Ins.
1046 Steel							
Mean	29.400 lbs.	21' 24"	12° 12'	.0625"	19' 29"	16°	.053"
Range	.32 lbs.	27'	9°	.088"	23'	8°	.085"
HF-1 Steel							
Mean	29.405 lbs.	28' 55"	13° 12'	.0703"	29' 12"	17° 42'	.0497"
Range	.27 lb.	32'	8°	.053	26'	7°	.058"

TOTAL SHEAR CYCLE AT ZERO LOAD

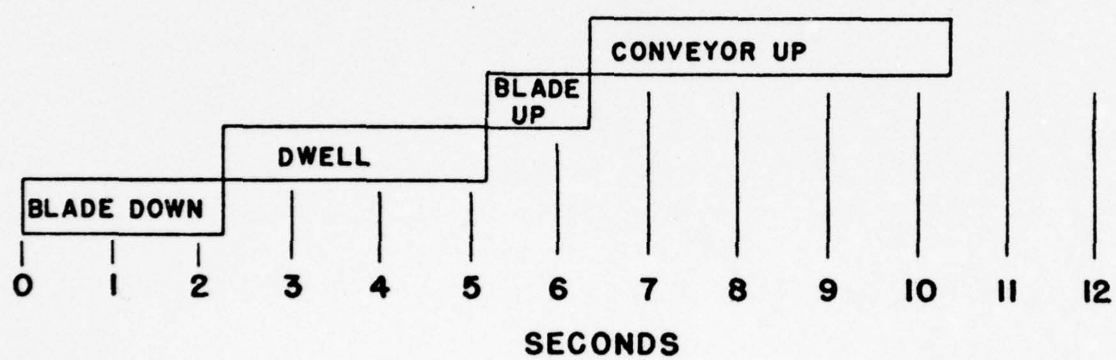
(NO ALLOWANCE FOR INFEED TIME)

SHORTEST POSSIBLE CYCLE TIME

=10.3 SECONDS

=5.82 PIECES / MINUTE

=349 PIECES / HOUR



TOOLING COST PER CUT

	GIRARD ESTIMATE	TOOLING VENDOR (ONE SET)	TOOLING VENDOR (2 SETS)
Knife First Cost	303.60	2,871.00	2,076.00
Regrind Cost, Minimum 1/3 x $303.60	101.20	725	725
Regrind Cost, Maximum 1/2 x $303.60	151.80	725	725
Regrind Life	6 grinds	6 grinds	6 grinds
Total Tooling Cost, Minimum	910.80	7,221.00	6,426.00
Total Tooling Cost, Maximum	1,214.40	7,221.00	6,426.00
Tool Life:	Min.	7 x 15,000 = 105,000 cuts	
	Max.	7 x 30,000 = 210,000 cuts	
	Typical	7 x 25,000 = 175,000 cuts	
Total Cost/Cut: Min.	0.43¢	3.44¢	3.06¢
Max.	1.16¢	6.88¢	6.12¢
Typical*	0.52¢	4.13¢	3.67¢

*Based on minimum regrind cost and 25,000 cuts/grind.

PARTIALLY SHEARED MULT, SHOWING TYPICALLY MINIMAL STOCK THAT CAN BE SHEARED WHILE RETAINING NORMAL SHEARED SURFACE.

DISTRIBUTION

Department of the Army
Deputy Chief of Staff for Research
Development and Acquisition
Attn: ODCSRDA(DAMA-CSM-P),
Mr. J. Mytrshyn
Washington, DC 20310

Commander
US Army Material Development and
Readiness Command
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Attn: DRCSA-R,
Col N.E. Vinson,
Room 7W-16

1 Attn: DRCSA-R,
Mr. Edson Garner
Room 8W-06

Commander
US Army Armament Command
2 Attn: DRSAR-PPI-W, Mr. Zahatko
Rock Island, IL 61201

Commander
Picatinny Arsenal
2 Attn: Scientific and Technical
Information Branch
Dover, NJ 07801

Commander
Scranton Army Ammunition Plant
Scranton, PA 18501

Commander
Twin Cities Army Ammunition Plant
New Brighton, MN 55112

Commander
Louisiana Army Ammunition Plant
Shreveport, LO 71130

Commander
Riverbank Army Ammunition Plant
Riverbank, CA 95367

Commander
Lone Star Army Ammunition Plant
Texarkana, TX 75501

Director
US Army Production Equipment Agency
2 Attn: DRXPE, Mr. Gallagher
Rock Island, IL 61201

Office of the Project Manager for
Munitions Production Base
Modernization and Expansion
Dover, NJ 07801

1 Attn: DRCPM-PBM-M,
Mr. C. Norbeck

1 Attn: DRCPM-PBM-M,
Mr. H. Krosser

1 Attn: DRCPM-PBM-G,
Mr. A. Williams

Defense Documentation Center (12)
Cameron Station
Alexandria, VA 22314

Commander
Frankford Arsenal
Philadelphia, PA 19137

1 Attn: AOA-M

1 Attn: TD

1 Attn: MDA-P

2 Attn: MTM

DISTRIBUTION (Cont)

Frankford Arsenal (Cont)

2 Attn: MTT

10 Attn: MTT-F

5 Attn: MTT-F,
Project File

3 Attn: TSP-L,
1 - Reference Copy
1 - Circulation Copy
1 - Tech Reports Editing

Printing & Reproduction Division
FRANKFORD ARSENAL
Date: 8 April 1977